IMPROVED MODEL FOR LOW COST SUN SENSOR ATTITUDE FILTERING

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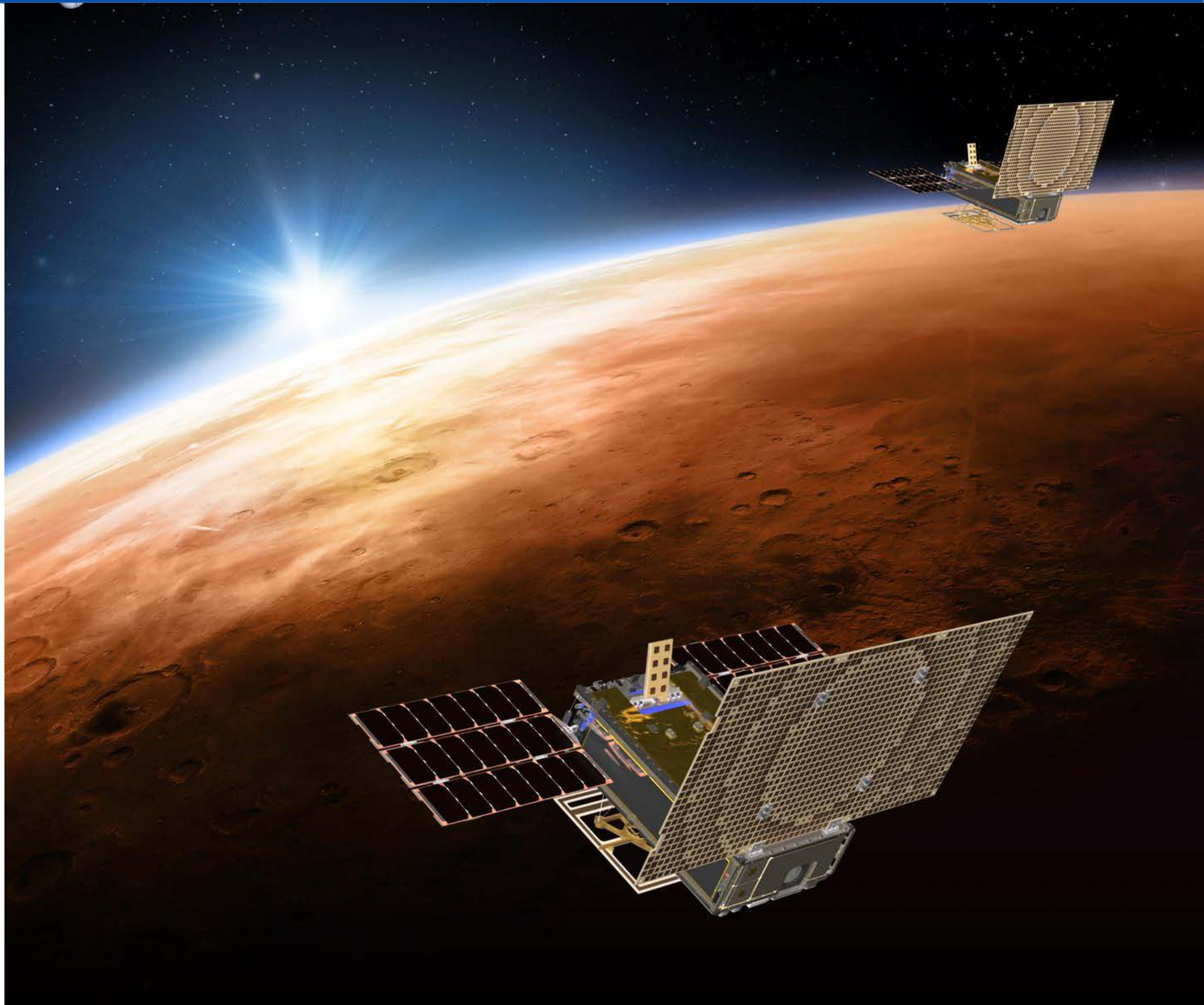
Contents

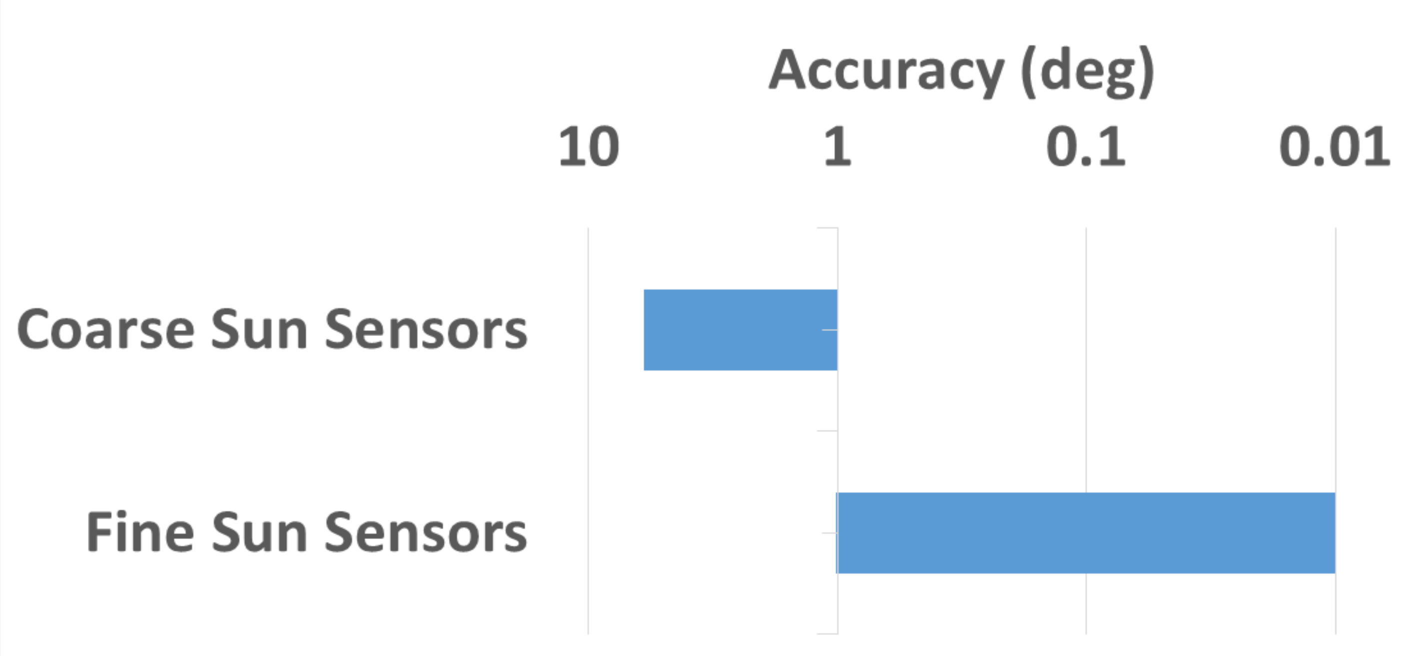
Growing Complexity

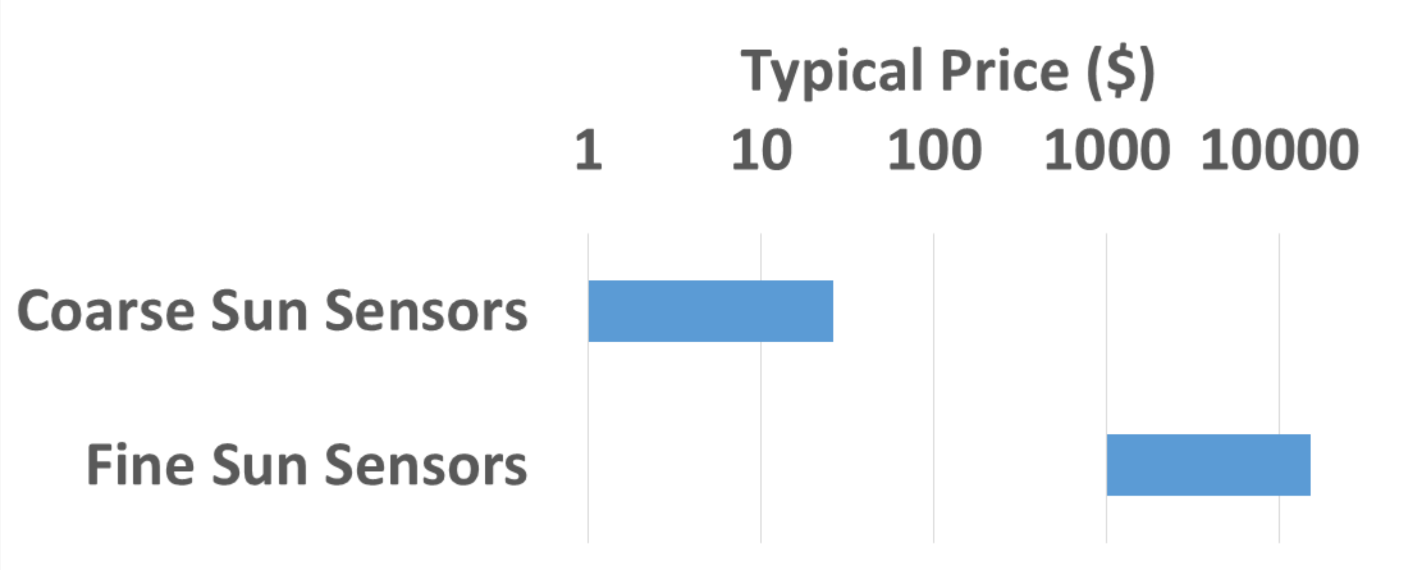
- Cubesats used to be seen as nothing more than toys.
- Missions have evolved from simple tech demos to profitable commercial ventures, scientific research, and even interplanetary communications relays.
- Strict budgets – volume, mass, dollars – are still in place.
- This establishes the need to “do more with less”.



Attitude Determination & Control (ADC)

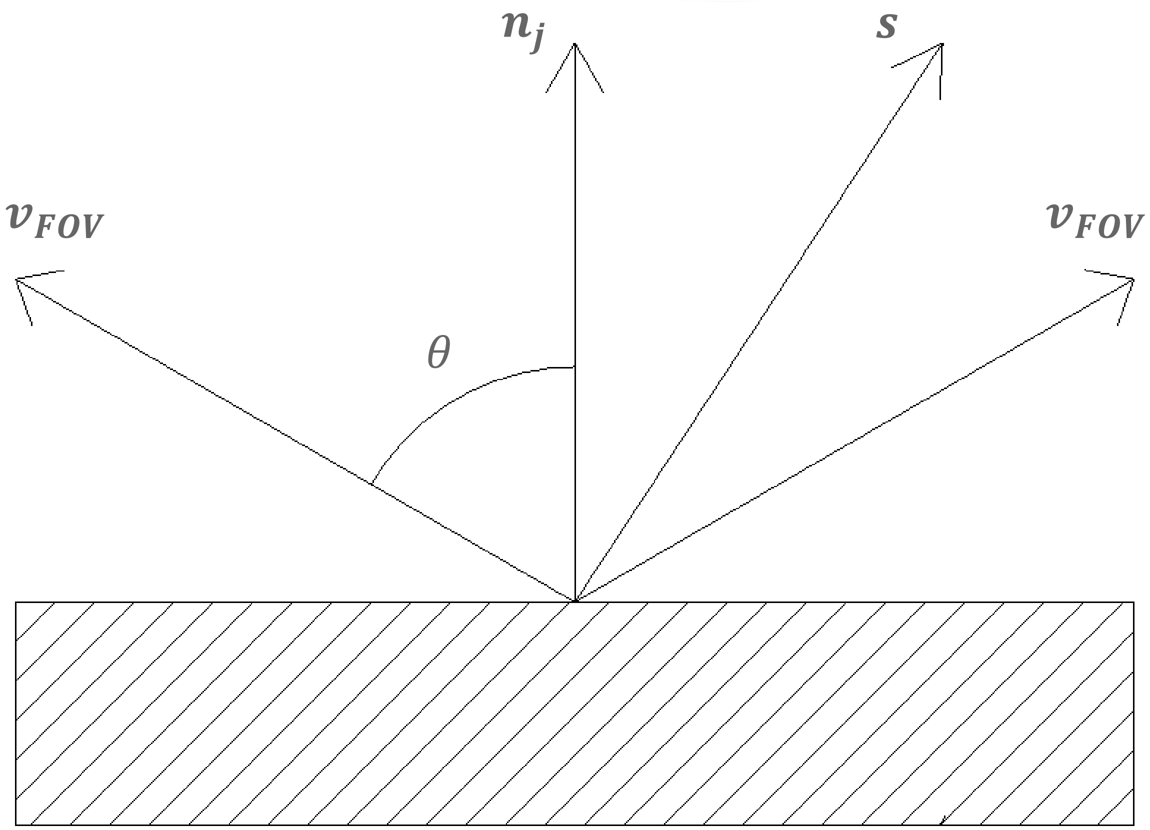
- ADC is a critical subsystem, responsible for pointing and controlling the spacecraft.
- ADC components can be among the most costly.
- A frequent trade study is comparing coarse to fine Sun sensor systems.
- The newly proposed voltage measurement model helps coarse Sun sensor systems approach fine sensor accuracy, while maintaining a low price.





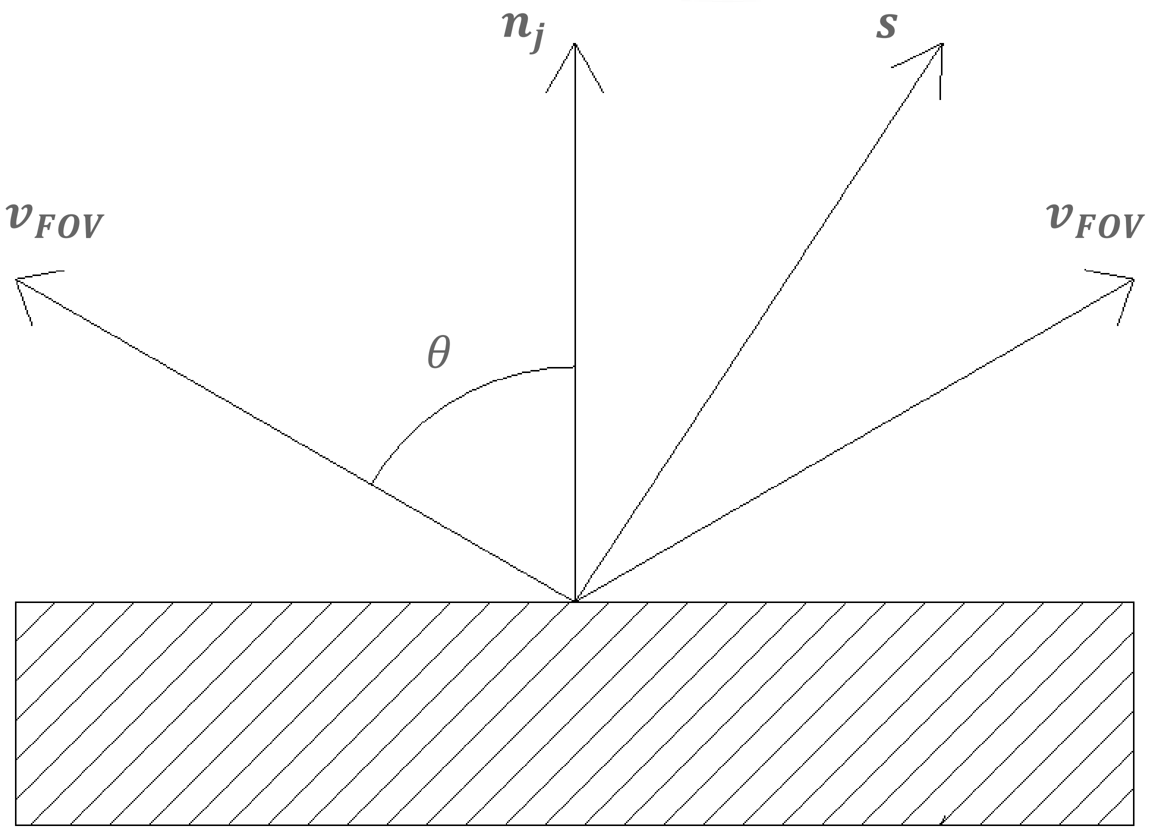
Standard Sun Measurement Model (SMM)

- Coarse Sun sensor systems are typically composed of photodiodes.
- The voltage across the jth photodiode, V_j, is a function of the angle between the photodiodes outward normal, $\boldsymbol{n_j}$, and the unit vector to the Sun, $\boldsymbol{s}$.
- $V_j = \begin{cases} V_{max}(\boldsymbol{n_j} \cdot \boldsymbol{s}) & \text{for } \boldsymbol{n_j} \cdot \boldsymbol{s} > 0 \\ 0 & \text{for } \boldsymbol{n_j} \cdot \boldsymbol{s} \leq 0 \end{cases}$
- With an array of voltage measurements, V_j, and a matrix of the photodiode outward normals, N, $\boldsymbol{s}$ can be computed by solving a linear least squares problem.
- $\boldsymbol{s}_{meas} = (N^T N)^{-1} N^T \left(\frac{V_j}{V_{max}} \right)$
- The SMM measures $\boldsymbol{s}_{meas}$ and then the attitude filter compares to a predicted Sun vector, $\boldsymbol{s}_{predict}$.



Voltage Measurement Model (VMM)

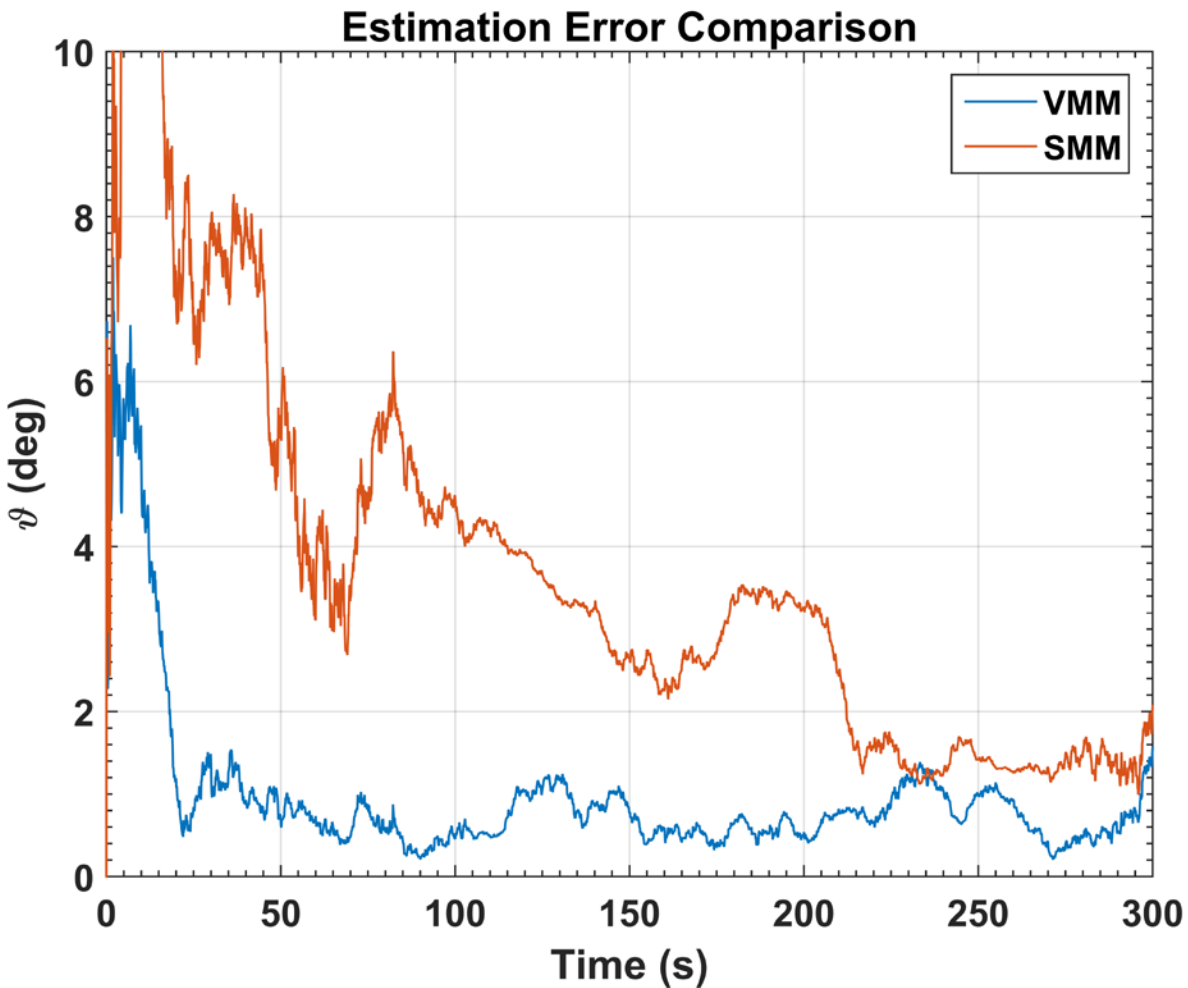
- The VMM uses the predicted Sun vector to predict photodiode voltages, and the attitude filter compares the predicted voltages to the measured voltages.
- $\boldsymbol{s}_{body} = A_{est}\boldsymbol{s}_{predict}$
- $V_{j,predict} = \begin{Bmatrix} V_{max}(\boldsymbol{n}_j \cdot \boldsymbol{s}_{body}) & \text{for } \boldsymbol{n_j} \cdot \boldsymbol{s_{body}} > 0 \\ 0 & \text{for } \boldsymbol{n_j} \cdot \boldsymbol{s_{body}} \leq 0 \end{Bmatrix}$
- No least squares problem to solve, and no possibility of an underdetermined system.
- VMM results in passing more independent measurements into the attitude filter for computing the attitude estimate.

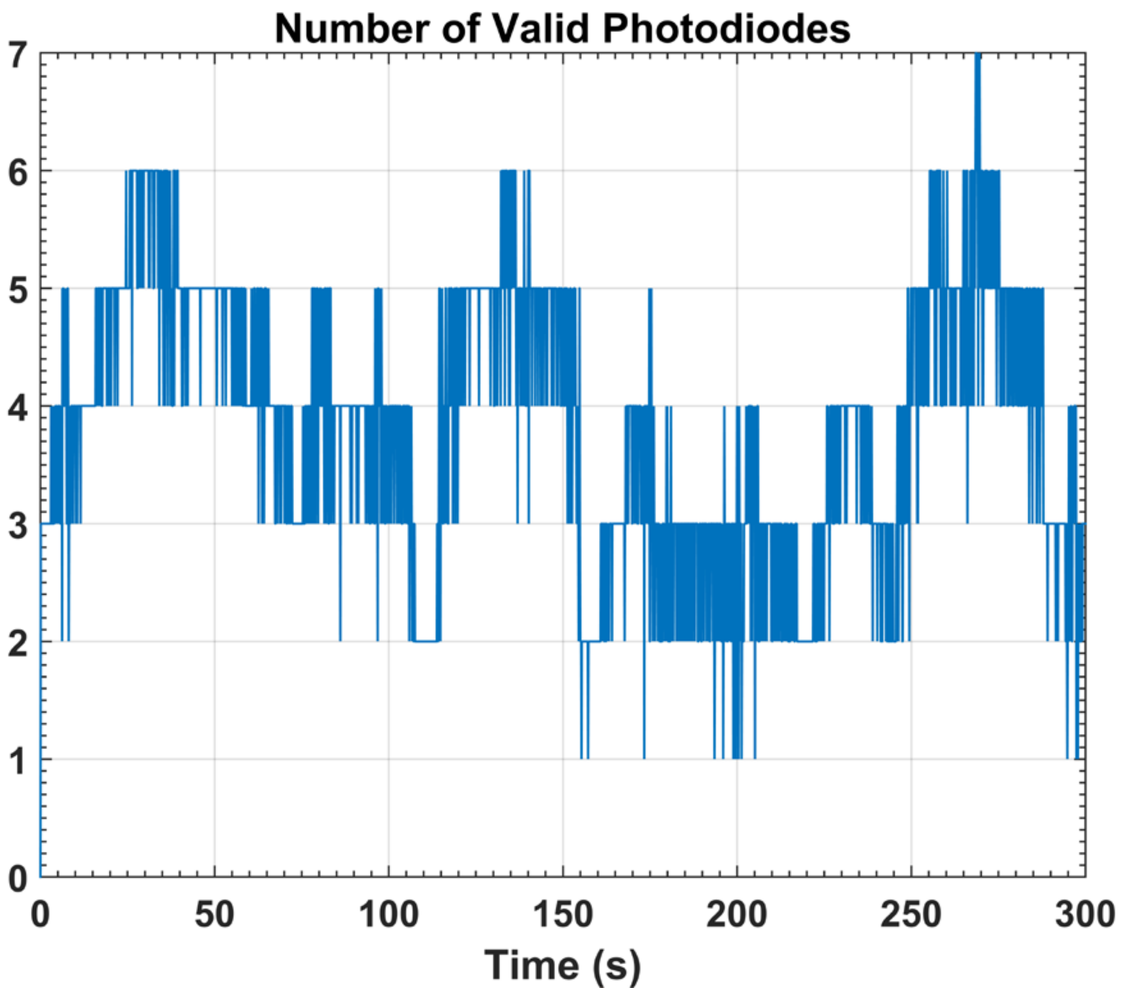


Simulation Numerical Methodology

- Euler's rotational equations with no control torques model rotational dynamics.
- External disturbance torques are included via models.
- Magnetometers and photodiodes modeled by adding zero-mean Gaussian noise to the true values. Rate gyros include Gaussian noise and bias error.
- Spacecraft initialized to a random attitude at about 2 deg/s, in sunlight.
- Sensor readings are passed into two parallel Kalman filters: one using SMM and the other using VMM.
- Differences in the estimated state are purely due to the model difference between SMM and VMM.
- Euler axis/angle parameterization used to compare model performance. The number of photodiodes with valid readings is used to explain performance differences.

Simulation Results





Conclusions and Contribution to the Field

- A new coarse Sun sensor measurement model was developed that uses photodiode voltages instead of computed Sun vectors.
- The new measurement model, compatible with previous iterations of hardware, significantly enhances the capabilities of coarse Sun sensor systems.
- Greatly increased cost-effectiveness of coarse Sun sensors relative to fine Sun sensors.
- The new model contributes a method of increasing subsystem performance to the field. Whether the purpose is academic, commercial, or scientific, all missions stand to benefit from this improvement.

Questions?